JCET
The Joint Center for Earth Systems Technology

Goddard
SPACE FLIGHT CENTER

Mapping the Oxidizing Capacity of the Global Remote Troposphere

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$$$: NASA ATom, NASA ACCDAM

Systematic Biases in Global Hydroxyl

Chemical proxies (e.g. methyl chloroform) tell us that models get OH wrong…

Methane Lifetime	
Observations:	11.2 ± 1.3 y
Global models:	9.7 ± 1.5 y

N/S Hemisphere Ratio	
Observations:	0.85 – 0.98
Global models:	1.28 ± 0.10

Naik et al. (2013); Prather et al. (2012); Montzka et al. (2000); Patra et al. (2014)

Wanted: New OH Constraints

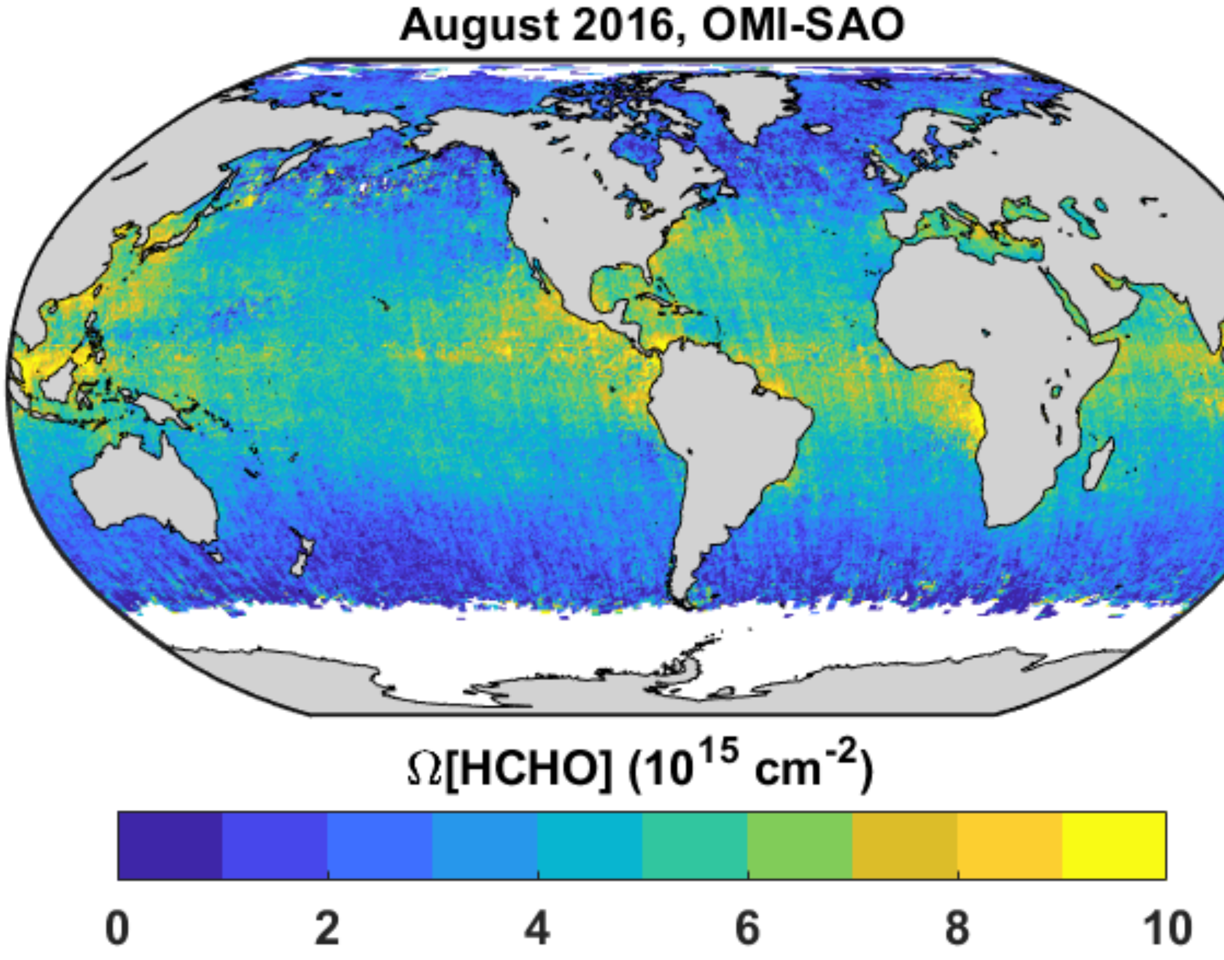
…but such constraints are annual and global/hemispheric at best.

- Seasonal cycles?
- Anthropogenic perturbations?
- Lightning? Wildfires? El Niño?

To build process-level understanding, we need to know how OH varies in <u>space</u> and <u>time</u>.

Formaldehyde (HCHO)

- Product of OH + CH_4 (and every other hydrocarbon)
- Atmospheric lifetime ~hours (lost via photolysis and OH)
- Observable via UV/Vis solar scatter (total column)



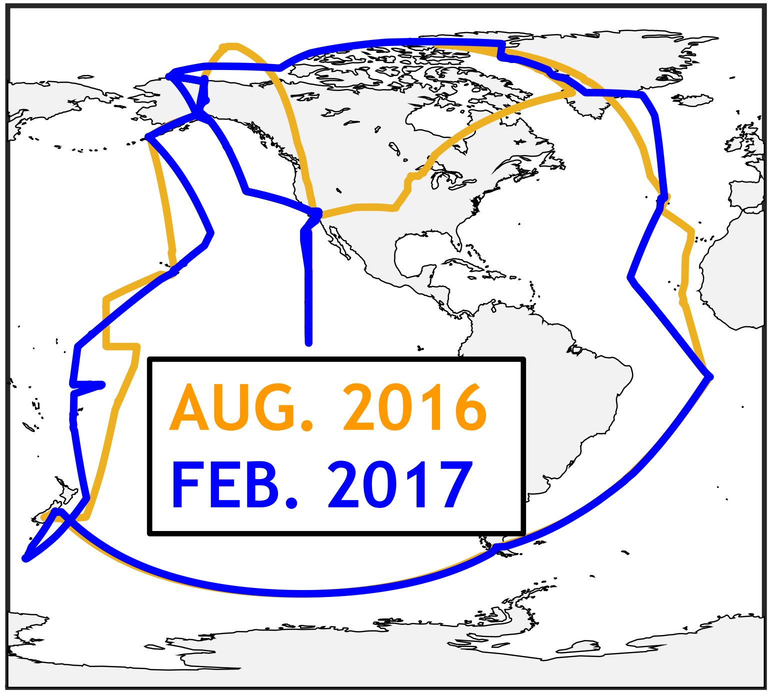
Recipe for Constraining Near-Global OH

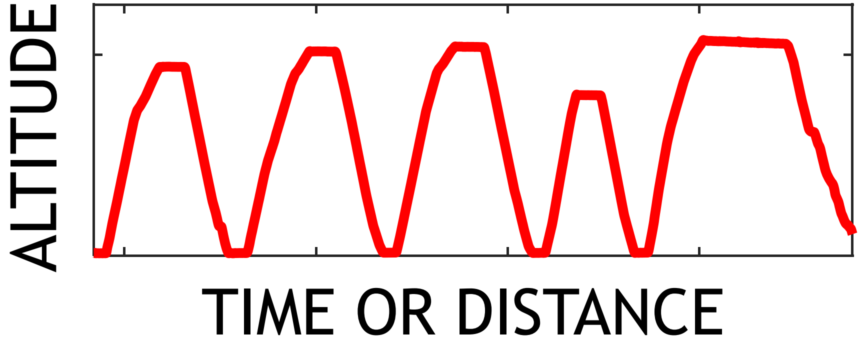
What is the link between Ω[HCHO] and Ω[OH]?

Is OMI Ω[HCHO] valid in remote regions?

Map of remote tropospheric column OH

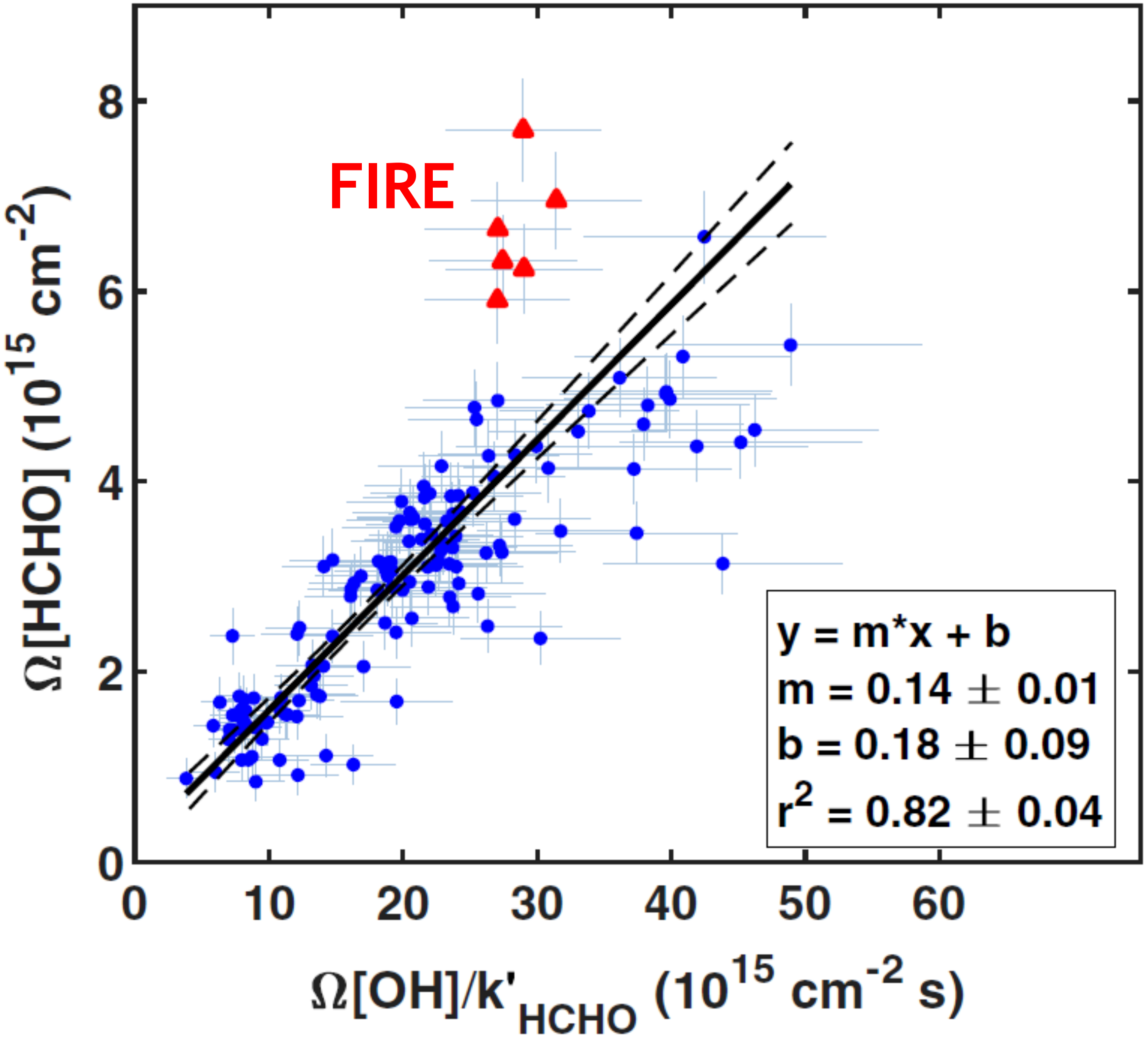
The Atmospheric Tomography Mission (ATom)





NASA DC-8 with *in situ* chemistry payload, including HCHO, OH, and friends

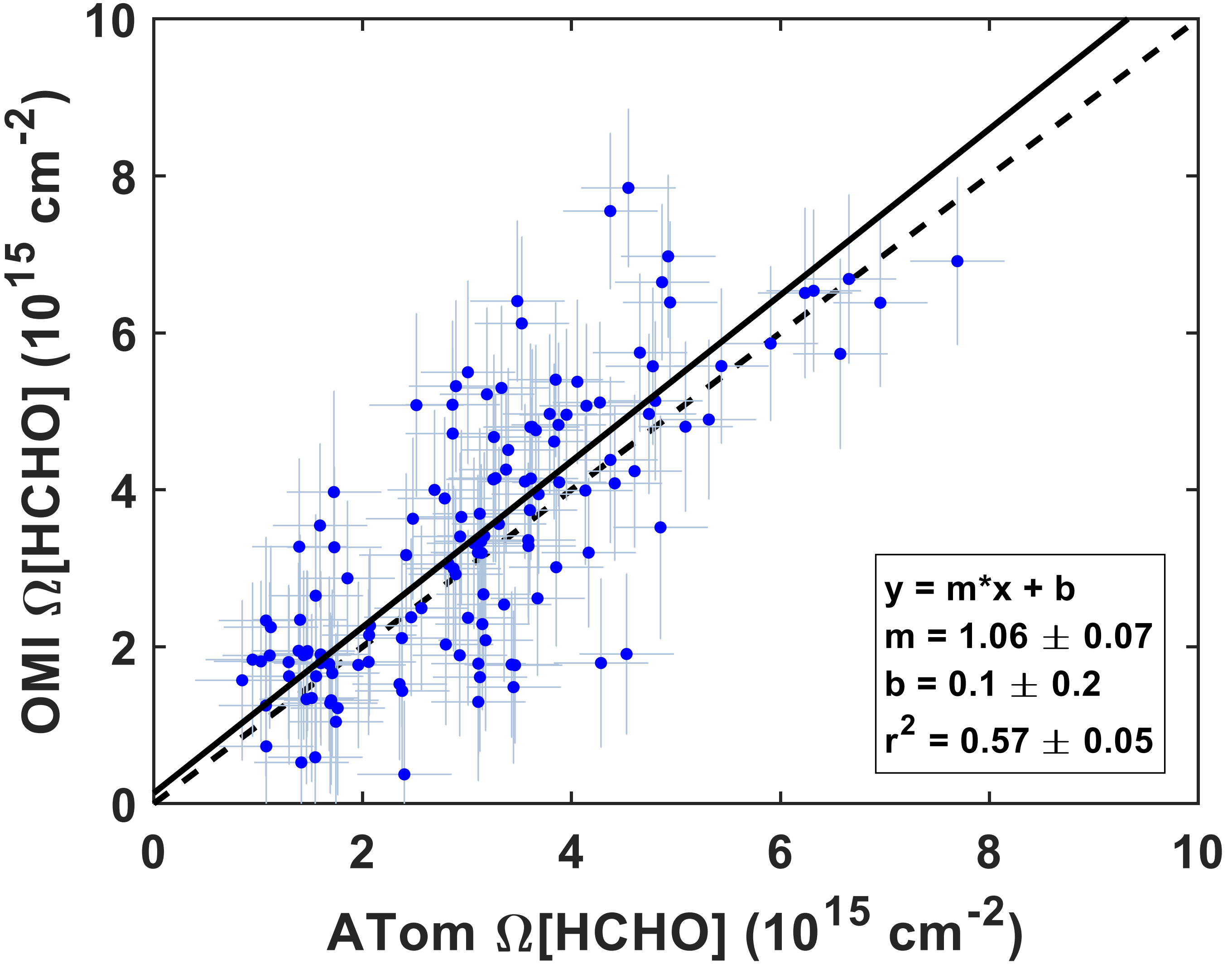
Ω[OH] and Ω[HCHO] Production/Loss Correlate



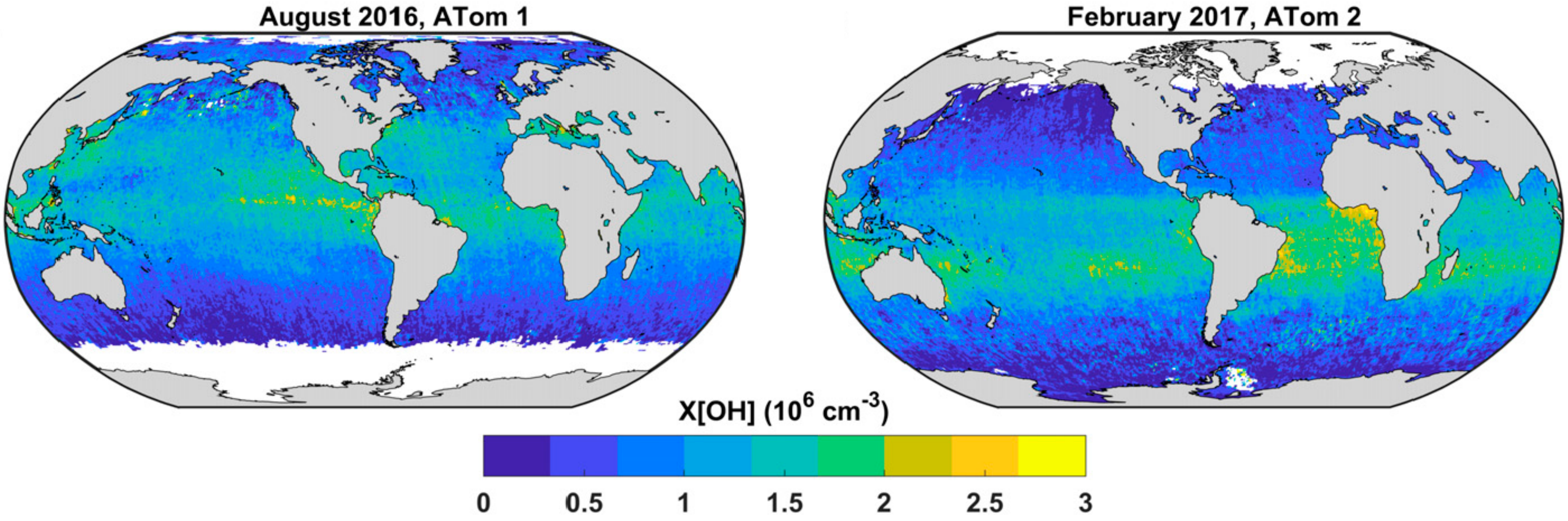
- Steady-state theory predicts a pseudo-linear relationship between OH concentrations and HCHO production/loss rates

- Slope depends mainly on OH sink distribution (CO, CH_4, other VOC)

OMI-SAO Ω[HCHO] is Valid in Remote Regions



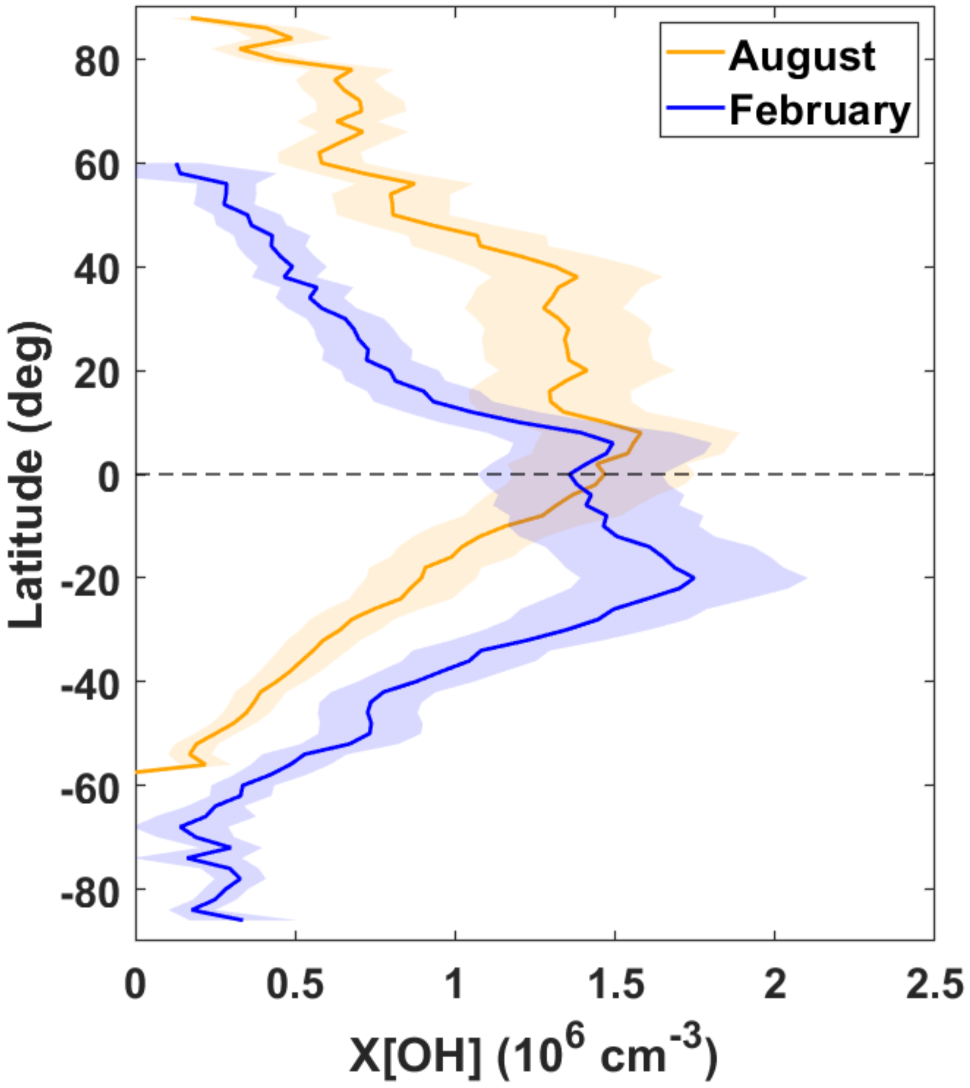
X[OH]: Monthly Tropospheric Mean Concentration



Domain mean: $(1.03 \pm 0.25) \times 10^6$ cm^{-3}

NH/SH ratio: 0.89 ± 0.06

Hemispheric Seasonality & Global Buffering



Individual hemispheres exhibit strong seasonality

but

"Global" average X[OH] is identical in both seasons

Take Away

- HCHO and OH are tightly coupled throughout the troposphere
- We can, and will, do better in the future
  - Satellite HCHO retrieval differences
  - Scaling factor dependence on CO, hydrocarbons, etc.
  - Expansion across the OMI record (2004 – now)

X[OH] offers spatial and temporal variability!

For the full story, see Wolfe et al., PNAS (2019)

EXTRA

Column Pseudo-Linear Model

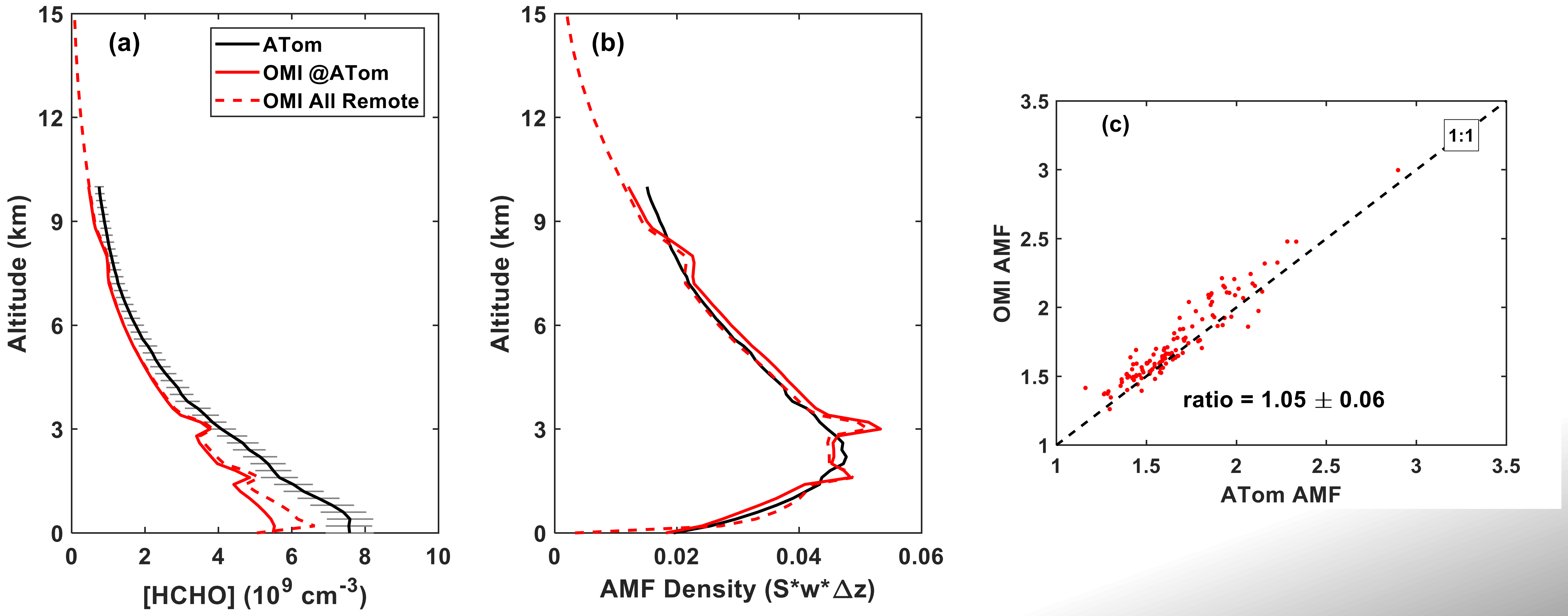
$$OH + X \longrightarrow \alpha_x HCHO \xrightarrow{h\nu, OH} \text{products}$$

$$\boxed{\Omega[HCHO] = s_{OH}\left(\frac{\Omega[OH]}{k'_{HCHO}}\right) + \Omega[HCHO]_0}$$

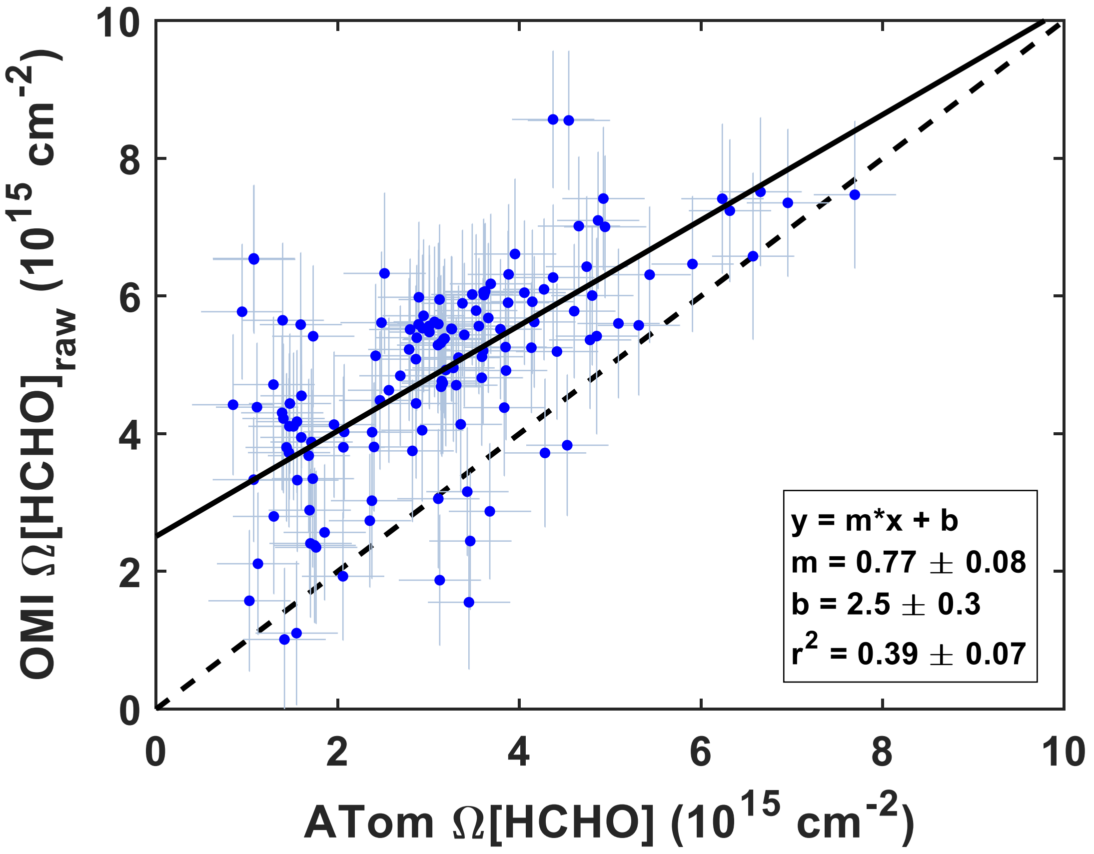
- Slope (s_{OH}) depends on OH sink distribution (CO, CH_4, other VOC) and should not vary much in remote regions

- k'_{HCHO} depends weakly on OH, but photolysis is dominant HCHO sink

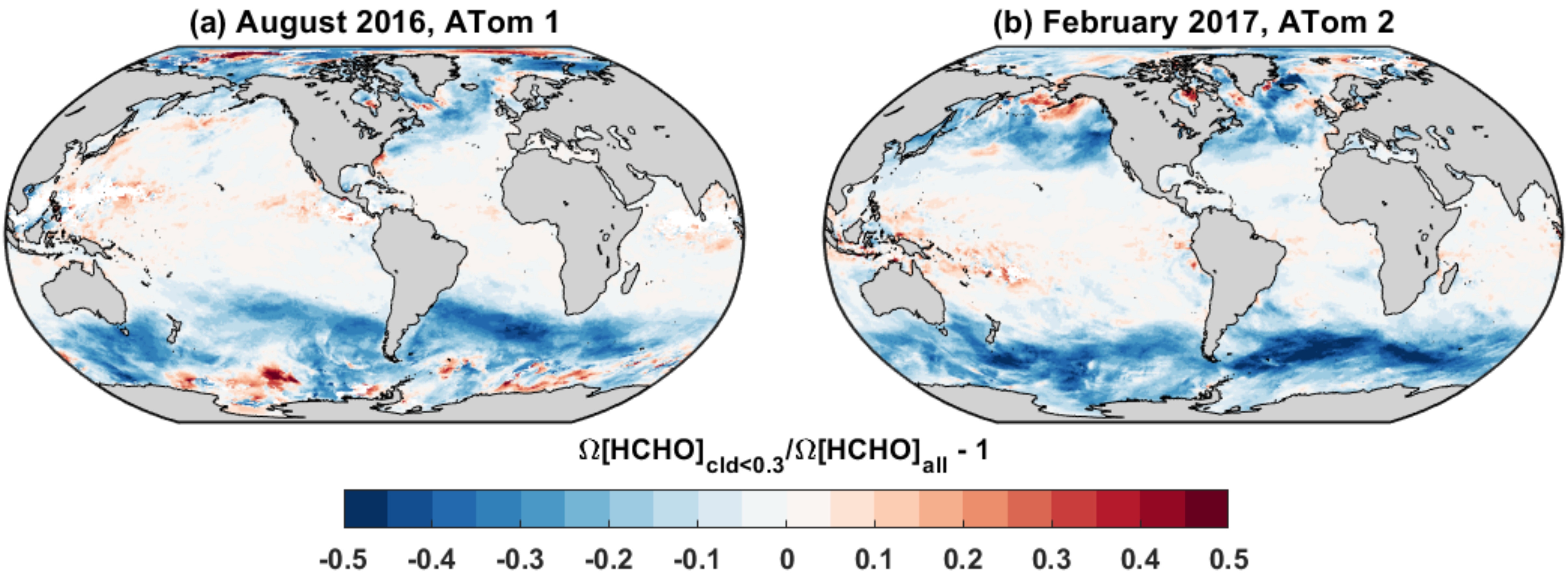
OMI AMF Evaluation



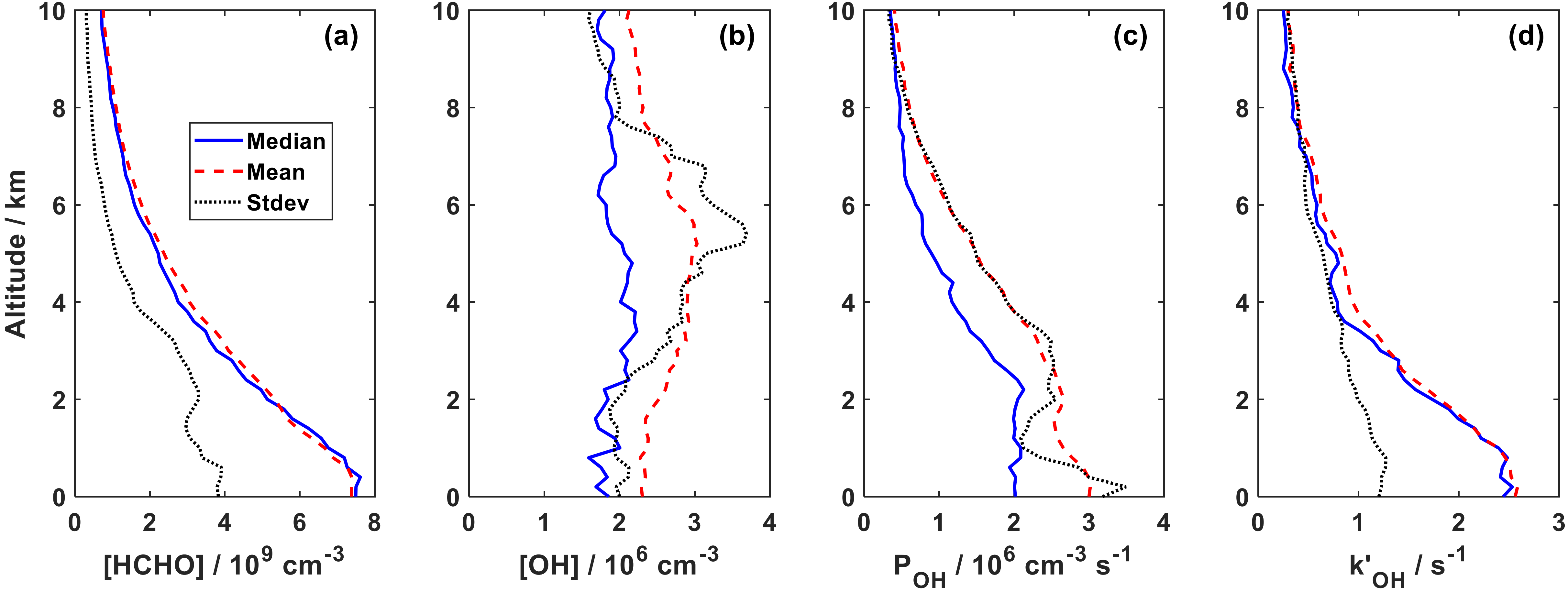
OMI Reference Sector Correction Evaluation



OMI HCHO Bias from Cloud Filtering



ATom Vertical Profiles

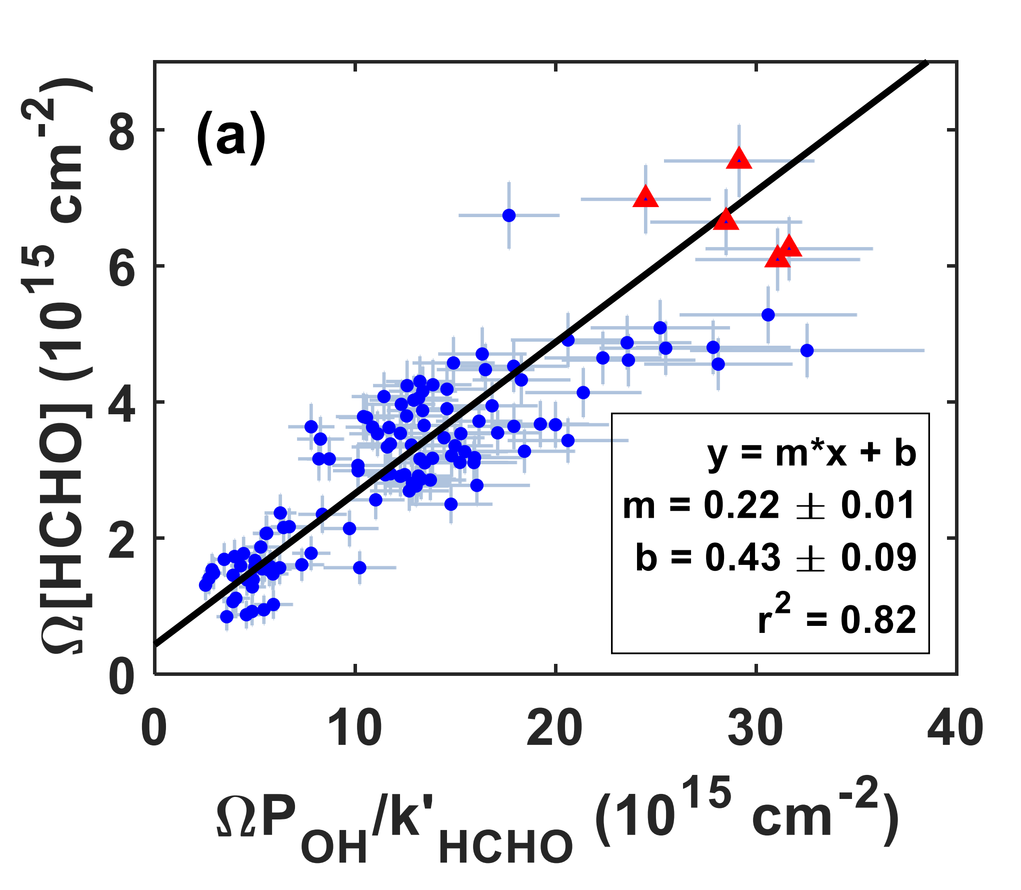


ATom OH Production and HCHO

$$\Omega[HCHO] = \alpha\frac{\Omega P_{OH}}{k'_{HCHO}} + \Omega[HCHO]_0$$

<u>OH Production</u>

O_3 + hv + H_2O → 2OH + O2	(38%)
HO_2 + NO → OH + NO_2	(35%)
HO_2 + O_3 → OH + $2O_2$	(15%)
H_2O_2 + hv → 2OH	(6%)
Other reactions	(6%)



Global Model Comparison